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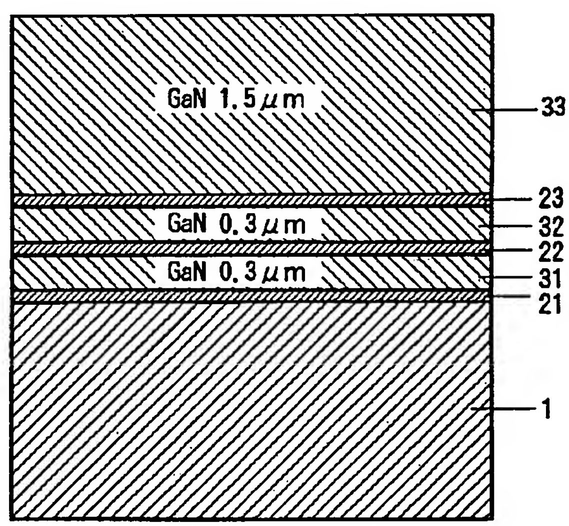
(54)【発明の名称】　3族窒化物半導体の製造方法及び半導体素子

(57)【要約】
【課題】異種物質基板上に成長させるAlGaInN 系の半導体の結晶性の改善。
【解決手段】異種物質の基板上に3族窒化物半導体($Al_xGa_yIn_{1-x-y}N$;X=0,Y=0,X=Y=0 を含む）を成長させる方法において、基板上に単結晶が成長しない温度で$Al_{x1}Ga_{y1}In_{1-x1-y1}N$(0≦X1≦1, 0≦Y1≦1, 0≦X1+Y1 ≦1)を形成したバッファ層と、単結晶が成長する温度で$Al_{x2}Ga_{y2}In_{1-x2-y2}N$(0≦X2≦1, 0≦Y2≦1, 0≦X2+Y2≦1, X1=X2, Y1=Y2 を含む）を形成した単結晶層とを交互に3層以上積層させ、その上に単結晶が成長する温度で目的とする$Al_{x3}Ga_{y3}In_{1-x3-y3}N$(0≦X3≦1, 0≦Y3≦1, 0≦X3+Y3≦1, X1又はX2=X3, Y1又はY2=Y3 を含む)から成る層を形成する。



【特許請求の範囲】

【請求項１】　異種物質の基板上に３族窒化物半導体($Al_xGa_yIn_{1-x-y}N$;X=0,Y=0,X=Y=0 を含む）を成長させる方法において、

前記基板上に単結晶が成長しない温度で$Al_{x1}Ga_{y1}In_{1-x1-y1}N$($0≦X1≦1$, $0≦Y1≦1$, $0≦X1+Y1≦1$)を形成したバッファ層と、単結晶が成長する温度で$Al_{x2}Ga_{y2}In_{1-x2-y2}N$($0≦X2≦1$, $0≦Y2≦1$, $0≦X2+Y2≦1$, X1=X2, Y1=Y2 を含む）を形成した単結晶層とを交互に３層以上積層させ、その上に単結晶が成長する温度で目的とする$Al_{x3}Ga_{y3}In_{1-x3-y3}N$($0≦X3≦1$, $0≦Y3≦1$, $0≦X3+Y3≦1$, X1又はX2=X3, Y1又はY2=Y3 を含む）から成る層を形成したことを特徴とする３族窒化物半導体の製造方法。

【請求項２】　前記バッファ層の厚さは１００～１０００Åであり、前記単結晶層の厚さは５００～３０００Åであることを特徴とする請求項１に記載の３族窒化物半導体の製造方法。

【請求項３】　前記バッファ層の成長温度は３５０～８００℃であることを特徴とする請求項１に記載の３族窒化物半導体の製造方法。

【請求項４】　前記バッファ層はAlN であり、前記単結晶層はGaN であることを特徴とする請求項１に記載の３族窒化物半導体の製造方法。

【請求項５】　前記基板は、サファイア又はSiC であることを特徴とする請求項１に記載の３族窒化物半導体の製造方法。

【請求項６】　異種物質の基板上に形成した３族窒化物半導体($Al_xGa_yIn_{1-x-y}N$;X=0,Y=0,X=Y=0 を含む）を素子層とした半導体素子において、

前記基板と前記素子層との間に、

前記基板上に単結晶が成長しない温度で形成された$Al_{x1}Ga_{y1}In_{1-x1-y1}N$($0≦X1≦1$, $0≦Y1≦1$, $0≦X1+Y1≦1$)から成るバッファ層と、単結晶が成長する温度で形成された$Al_{x2}Ga_{y2}In_{1-x2-y2}N$($0≦X2≦1$, $0≦Y2≦1$, $0≦X2+Y2≦1$, X1=X2, Y1=Y2 を含む）から成る単結晶層とを交互に３層以上積層させた中間層が介在されていることを特徴とする半導体素子。

【請求項７】　前記バッファ層の厚さは１００～１０００Åであり、前記単結晶層の厚さは５００～３０００Åであることを特徴とする請求項６に記載の半導体素子。

【請求項８】　前記バッファ層の成長温度は３５０～８００℃であることを特徴とする請求項６に記載の半導体素子。

【請求項９】　前記バッファ層はAlN であり、前記単結晶層はGaN であることを特徴とする請求項６に記載の半導体素子。

【請求項１０】　前記基板は、サファイア又はSiC であることを特徴とする請求項６に記載の半導体素子。

【請求項１１】　前記素子層は光素子の基底層であることを特徴とする請求項６に記載の半導体素子。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は３族窒化物半導体を用いた発光素子に関する。

【０００２】

【従来技術】従来、青色のレーザダイオードとして、サファイア基板上にバッファ層を形成して、そのバッファ層上にAlGaInN 系の化合物半導体のダブルヘテロ接合を形成した構造のものが知られている。その化合物半導体は直接遷移型であることから発光効率が高いこと、光の３原色の１つである青色を発光色とすること等から注目されている。

【０００３】

【発明が解決しようとする課題】しかし、従来の上記構造のレーザダイオードは、バッファ層を用いているものの、異種物質の基板上にAlGaInN 系の化合物半導体を成長させたものであるため、結晶性が未だに良くない。即ち、この格子欠陥は基板面から発光層へ垂直に貫通しており、発光層での格子欠陥密度は10^9～$10^{10}/cm^2$程度存在している。この格子欠陥密度が高いことが、発光効率を低下させ、動作寿命を短縮させている。本発明は、上記課題を解決するために成されたものであり、その目的は、異種物質基板上に成長させるAlGaInN 系の化合物半導体の結晶性を改善し、その化合物半導体を用いた半導体素子の特性を改善することである。

【０００４】

【課題を解決するための手段】本発明は、異種物質の基板上に３族窒化物半導体($Al_xGa_yIn_{1-x-y}N$;X=0,Y=0,X=Y=0 を含む）を成長させる方法において、基板上に単結晶が成長しない温度で$Al_{x1}Ga_{y1}In_{1-x1-y1}N$($0≦X1≦1$, $0≦Y1≦1$, $0≦X1+Y1≦1$)を形成したバッファ層と、単結晶が成長する温度で$Al_{x2}Ga_{y2}In_{1-x2-y2}N$($0≦X2≦1$, $0≦Y2≦1$, $0≦X2+Y2≦1$, X1=X2, Y1=Y2 を含む）を形成した単結晶層とを交互に３層以上積層させ、その上に単結晶が成長する温度で目的とする$Al_{x3}Ga_{y3}In_{1-x3-y3}N$($0≦X3≦1$, $0≦Y3≦1$, $0≦X3+Y3≦1$, X1又はX2=X3, Y1又はY2=Y3 を含む）から成る層を形成したことを特徴とする。

又、他の発明の特徴は、そのように形成した$Al_{x3}Ga_{y3}In_{1-x3-y3}N$の層を素子層の基底層とした半導体素子である。

【０００５】この構成により、基板面から縦に延びる格子欠陥がバッファ層と単結晶層との繰り返しにより途中で遮断され、目的とする単結晶の層には至らない。特に基板面からの転位がバッファ層の単結晶の50～1000Åに閉じ込められ、上の層に伝搬されることを防ぐ。よって、素子を形成するための半導体層における格子欠陥密度は低くなり、異種物質の基板上にも良質な$Al_{x3}Ga_{y3}In_{1-x3-y3}N$から成る単結晶半導体が得られる。又、その単結晶の半導体を基底層として素子を形成した場合には、素子を形成する層の結晶性が高くなり、素子の特性を向

上させることができる。特に、発光素子を形成した場合には、発光効率、素子寿命、発光輝度を改善することができる。

【０００６】請求項２、７のように、バッファ層の厚さを１００～１０００Å、単結晶層の厚さを５００～３０００Åとすることで、又、請求項３、８のように、バッファ層の成長温度を３５０～８００℃とすることで、格子欠陥が基板面から目的とする半導体層に伸びることを効率良く防止できる。また、単結晶層の厚さが３０００Åを越えると歪が大きくなり好ましくない。

【０００７】バッファ層と単結晶層は、一般式$Al_xGa_yIn_{1-X-Y}N$の４元、３元、２元の窒化物半導体とすることができる。特に、請求項４のように、バッファ層をAlN 、単結晶層をGaN とすることで、目的とするGaN の層の格子欠陥密度を大きく低下させることができる。又、基板には、サファイア又はSiC 等を用いることができる。尚、バッファ層と単結晶層との繰り返し数は任意である。また、最後のバッファ層成層後そのまま昇温し、単結晶層を成長させることが、単結晶の結晶性からも、工程の簡易性からも好ましい。

【０００８】

【実施例】サファイア基板上に次のように目的とする$Al_{x3}Ga_{y3}In_{1-X3-Y3}N$から成る層を形成した。各層は、有機金属化合物気相成長法(以下「MOVPE 」と記す) による気相成長により形成された。用いられたガスは、NH_3 とキャリアガスH_2又はN_2とトリメチルガリウム$(Ga(CH_3)_3)$ (以下「TMG 」と記す) とトリメチルアルミニウム$(Al(CH_3)_3)$ (以下「TMA」と記す) である。

【０００９】まず、有機洗浄及び熱処理により洗浄した厚さ100 ～400 μmの単結晶のサファイア基板１をMOVPE 装置の反応室に載置されたサセプタに装着する。次に、常圧でH_2を流速2 liter/分で反応室に流しながら温度1100℃でサファイア基板１を気相エッチングした。

【００１０】次に、温度を 400℃まで低下させて、H_2を20 liter／分、NH_3 を10 liter／分、TMA を 1.8×10^{-5}モル／分で供給して図１に示す様に AlNのバッファ層２１が約 500Åの厚さに形成された。次に、サファイア基板１の温度を1150℃に保持し、H_2を20 liter／分、NH_3を10 liter／分、TMG を 1.7×10^{-4}モル／分で供給して、膜厚約0.3 μmのGaN から成る単結晶層３１を形成した。

【００１１】次に、サファイア基板１の温度を、再度、 400℃まで低下させて、バッファ層２１の形成と同一条件で、 500Åの厚さのAlN から成るバッファ層２２を形成した。次に、サファイア基板１の温度を、再度、1150℃に上げて、単結晶層３１の形成と同一条件で、厚さ0.3 μmのGaN から成る単結晶層３２を形成した。さらに、サファイア基板１の温度を、再度、 400℃まで低下させて、その単結晶層３２の上に、同様に、バッファ層２３を形成した。そして、サファイア基板１の温度を、再度、1150℃に上げて、単結晶層３１の形成と同一条件で、厚さ1.5 μmのGaN から成る目的とする単結晶層３３を形成した。

【００１２】この単結晶層３３をKOH によりエッチングして、エッチピット法により表面の転位密度を電子走査顕微鏡で撮像して測定した。その結果は、8×10^5 cm^2 であった。従来のように、サファイア基板１上に１層のAlN から成るバッファ層２２を形成し、その上に目的とするGaN から成る単結晶層を形成した場合のエッチピット密度が4×10^7 /cm^2であるので、本実施例の製造方法により、エッチピット密度は1/50に低下した。

【００１３】バッファ層を多層構造とすることで、エッチピットを減少できる理由は、次のように考えられる。ピットの形状は電子顕微鏡による観察により六角形である。AlN のバッファ層上に形成されるGaN の成長初期は、六角形の島状結晶である。その後、結晶成長と共にバッファ層はGaN に覆われることになるが、格子欠陥部分は残されてやはり六角形のピットとなるものと考えられる。しかし、AlN のバッファ層とGaN の単結晶層を多重周期構造とすることで、AlN 層がGaN 層とうまく干渉して格子欠陥が塞がれたものと思われる。

【００１４】上記実施例では、バッファ層にはAlN を用いたが他の２元系のGaN 、InN や３元系のAlGaN 、InGaN 、４元系のAlGaInN 等を用いることができる。この場合にバッファ層は単結晶が成長しない低い温度で形成され、その厚さは100 ～1000Åが望ましい。又、バッファ層上に形成される単結晶層の物質は、バッファ層と物質及び組成比が同一でも、異種物質又は同種物質でも組成比が異なるものでも良い。この単結晶層には、GaN の他、任意組成比の３元系のAlGaN 、InGaN 、任意組成比の４元系のAlGaInN を用いることができる。この単結晶層の成長温度は単結晶が成長できる温度である。一般的に、厚さは500 ～3000Åの範囲が望ましい。又、バッファ層と単結晶層との繰り返し回数は任意である。

【００１５】さらに、目的とする単結晶の半導体層は、２元、３元、４元系の３族窒化物半導体$Al_{x3}Ga_{y3}In_{1-X3-Y3}N$$(0\leq X3\leq1,\ 0\leq Y3\leq1,\ 0\leq X3+Y3\ \leq1)$を用いることができる。

【００１６】次に、本製造方法を用いてレーザダイオード１０を製造した。図１において、レーザダイオード１０は、サファイア基板１を有しており、そのサファイア基板１上に中間層２が形成されている。中間層２は、図１に示す構造と同一である。即ち、中間層２は、厚さ500 ÅのAlN から成るバッファ層２１、厚さ0.3 μm から成る単結晶層３１、500 ÅのAlN から成るバッファ層２２、厚さ0.3 μm から成る単結晶層３２、500 ÅのAlN から成るバッファ層２３の多層構造で構成されている。

【００１７】そして、その中間層２の上には、順に、電子濃度2×10^{18}/cm^3のシリコンドープGaN から成る高キャリア濃度n^+ 層３、電子濃度 2×10^{18}/cm^3のシリコン

ドープのAlGaN から成るｎ伝導型のクラッド層４、膜厚約0.05μｍのInGaN から成る活性層５、ホール濃度１×10^{18}/cm^3、濃度２×10^{20}/cm^3にマグネシウムがドープされたAlGaN から成るｐ伝導型のクラッド層６１、ホール濃度１×10^{18}/cm^3、マグネシウム濃度 2×10^{20}/cm^3のマグネシウムドープのGaN から成るコンタクト層６２が形成されている。そして、コンタクト層６２上にはSiO_2層９が形成され、SiO_2層９の窓部を介してコンタクト層６２に接合するNiから成る電極７が形成されている。さらに、高キャリア濃度n^+ 層３の上にその層３に接合するNiから成る電極８が形成されている。

【００１８】次に、この構造のレーザダイオード１０の製造方法について説明する。上記レーザダイオード１０は、上述したMOVPE による気相成長により製造された。用いられたガスは、NH_3 とキャリアガスH_2又はN_2とTMGとTMA とトリメチルインジウム($In(CH_3)_3$)（以下「TMI」と記す）と、シラン(SiH_4)とシクロペンタジエニルマグネシウム($Mg(C_5H_5)_2$)(以下「CP_2Mg 」と記す）である。

【００１９】まず、有機洗浄及び熱処理により洗浄した厚さ100 ～400 μｍの単結晶のサファイア基板１をMOVPE 装置の反応室に載置されたサセプタに装着する。次に、常圧でH_2を流速2 liter/分で反応室に流しながら温度1100℃でサファイア基板１を気相エッチングした。

【００２０】次に、温度を 400℃まで低下させて、H_2を20 liter／分、NH_3 を10 liter／分、TMA を 1.8×10^{-5}モル／分で供給してAlN のバッファ層２１を約 500Åの厚さに形成した。次に、サファイア基板１の温度を1150℃に保持し、H_2を20 liter／分、NH_3 を10 liter／分、TMG を 1.7×10^{-4}ル／分で、４分間供給して、膜厚約0.3 μｍのGaN から成る単結晶層３１を形成した。

【００２１】次に、サファイア基板１の温度を、再度、 400℃まで低下させて、バッファ層２１の形成と同一条件で、 500Åの厚さのAlN から成るバッファ層２２を形成した。次に、サファイア基板１の温度を、再度、1150℃に上げて、単結晶層３１の形成と同一条件で、厚さ0.3 μｍのGaN から成る単結晶層３２を形成した。さらに、サファイア基板１の温度を、再度、 400℃まで低下させて、その単結晶層３２の上に、同様に、バッファ層２３を形成した。

【００２２】次に、サファイア基板１の温度を1150℃に保持し、H_2を20 liter／分、NH_3 を10 liter／分、TMG を 1.7×10^{-4}ル／分、H_2ガスにより0.86ppm に希釈されたシランを200ml/分で供給して、膜厚約2.2 μｍ、電子濃度 2×10^{18}/cm^3のシリコンドープのGaN から成る高キャリア濃度n^+ 層３を形成した。

【００２３】次に、サファイア基板１の温度を1100℃に保持し、N_2又はH_2を10 liter／分、NH_3 を10 liter／分、TMG を1.12×10^{-4}モル／分、TMA を0.47×10^{-4}モル／分、及び、H_2ガスにより0.86ppm に希釈されたシランを10×10^{-9}mol/分で供給して、濃度２×10^{18}/cm^3のシリコンドープのAlGaN から成るｎ伝導型のクラッド層４を形成した。

【００２４】続いて、温度を850 ℃に保持し、N_2又はH_2を20 liter／分、NH_3 を10 liter／分、TMG を1.53×10^{-4}モル／分、及び、TMI を0.02×10^{-4}モル／分で供給して、0.05μｍのInGaN から成る活性層５を形成した。

【００２５】続いて、温度を1100℃に保持し、N_2又はH_2を20 liter／分、NH_3 を10 liter／分、TMG を1.12×10^{-4}モル／分、TMA を0.47×10^{-4}モル／分、及び、CP_2Mgを2×10^{-4}モル／分で供給して、マグネシウム(Mg)ドープのAlGaN から成るｐ伝導型のクラッド層６１を形成した。クラッド層６１のマグネシウムの濃度は２×10^{20}/cm^3である。この状態では、クラッド層６１は、まだ、抵抗率10^8 Ωcm以上の絶縁体である。

【００２６】続いて、温度を1100℃に保持し、N_2又はH_2を20 liter／分、NH_3 を10 liter／分、TMG を1.12×10^{-4}モル／分、及び、CP_2Mg を 4×10^{-4}モル／分で供給して、膜厚約0.2 μｍのマグネシウム(Mg)ドープのGaN から成るコンタクト層６２を形成した。コンタクト層６２のマグネシウムの濃度は 2×10^{20}/cm^3である。この状態では、コンタクト層６２は、まだ、抵抗率10^8 Ωcm以上の絶縁体である。

【００２７】次に、電子線照射により、コンタクト層６２、クラッド層６１は、ホール濃度１×10^{18}/cm^3、抵抗率 2Ωcmのｐ伝導型半導体となった。~~このようにして、~~多層構造のウエハが得られた。

【００２８】次に、コンタクト層６２の上に、スパッタリングによりSiO_2層９を2000Åの厚さに形成し、そのSiO_2層９上にフォトレジストを塗布した。そして、フォトリソグラフにより、コンタクト層６２上において、高キャリア濃度n^+ 層３に対する電極形成部位のフォトレジストを除去した。次に、フォトレジストによって覆われていないSiO_2層９をフッ化水素酸系エッチング液で除去した。

【００２９】次に、フォトレジスト及びSiO_2層９によって覆われていない部位のコンタクト層６２、クラッド層６１、活性層５、クラッド層４を、真空度0.04Torr、高周波電力0.44W/cm^2 、BCl_3ガスを10 ml/分の割合で供給しドライエッチングした後、Arでドライエッチングした。この工程で、高キャリア濃度n^+ 層３に対する電極取出しのための孔Ａが形成された。

【００３０】次に、SiO_2層９に対して、フォトレジストの塗布、フォトリソグラフィ工程、湿式エッチングを行い、SiO_2層９のコンタクト層６２の電極形成部位に窓を形成した。

【００３１】次に、試料の上全面に、一様にNiを蒸着し、フォトレジストの塗布、フォトリソグラフィ工程、エッチング工程を経て、高キャリア濃度n^+ 層３及びコンタクト層６２に対する電極８，７を形成した。その

後、上記の如く処理されたウエハをレーザのキャビティの長さ方向に短冊状に切断し、その方向に直角にへき開してレーザダイオードチップを形成した。

【0032】このように中間層2を低温成長のAlN から成るバッファ層の多重層とすることで、高キャリア濃度 n^+ 層3、クラッド層4、活性層5、クラッド層61、コンタクト層62の結晶性を向上させることができた。

【0033】尚、中間層2は、製造方法の実施例で示したように、種種の変形が考えられる。又、上記の実施例では、活性層5の構造をInGaN の単層としたが、それぞれ、厚さが100 ÅのInGaN とGaN とで構成された多重量子井戸構造でも良い。活性層5の厚さは100 ～1000Åである。本実施例では、レーザダイオードについて説明したが、発光ダイオード、受光素子等の光素子を含む各種のGaN 系電子デバイスに適用できることは言うまでもない。

【0034】又、クラッド層4、61、活性層5は、一般的に、$Al_xGa_yIn_{1-x-y}N$でも良い。組成比ｘ：ｙ：１－ｘ－ｙはレーザの発振波長に応じて決定される。

【0035】ｐ型化は、電子線照射の他、熱処理、N_2プラズマガス中での熱処理、レーザ照射により行うことができる。

【図面の簡単な説明】

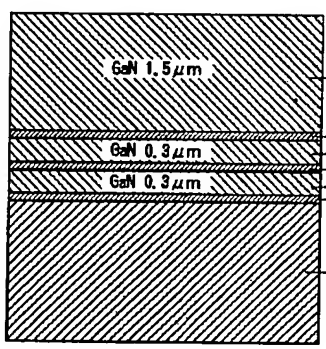
【図１】本発明の具体的な実施例に係る製造方法を示した半導体層の断面図。

【図２】本発明の具体的な実施例に係るレーザダイオードの構成を示した構成図。

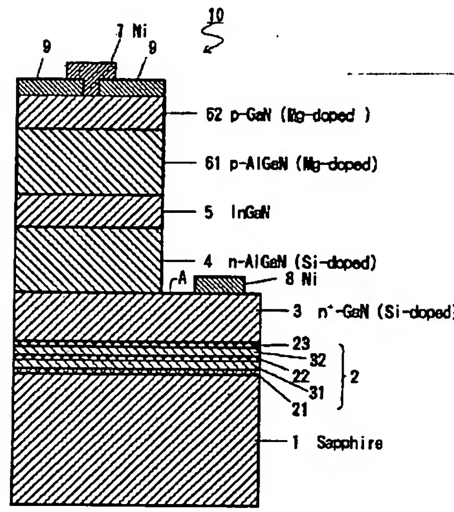
【符号の説明】

１０…レーザダイオード
１…サファイア基板
２…中間層
２１，２２，２３…バッファ層
３１，３２…単結晶層
３…高キャリア濃度ｎ$^+$ 層
４…クラッド層
５…活性層
６１…クラッド層
６２…コンタクト層
７，８…電極
９…SiO_2層

【図１】



【図２】



フロントページの続き

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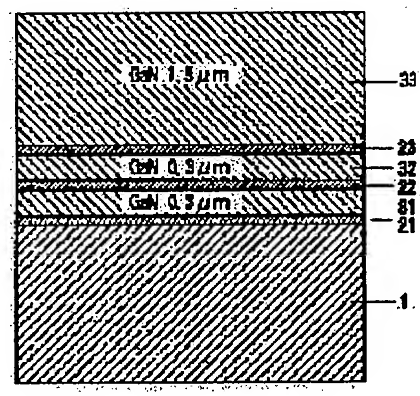
(54) MANUFACTURE OF GROUP III NITRIDE SEMICONDUCTOR AND SEMICONDUCTOR DEVICE

(57)Abstract:
PROBLEM TO BE SOLVED: To improve the crystallinity of AlGaInN semiconductor grown on a different type substance substrate.
SOLUTION: The method for growing group III nitride semiconductor (AlxGayIn1-x-yN; includes X=0, Y= 0, X=Y=0) on a different substance substrate comprises the steps of alternately laminating buffer layers 21 to 23 formed with Alx1Gay1In1-x1-y1N (0≤X1≤1, 0≤Y1≤1, 0≤X1+Y1≤1) at the temperature that a single crystal is not grown on the substrate and single crystal layers 31, 32 formed with Alx2Gay2In1-X2-Y2N (includes 0≤X2≤1, 0≤Y2≤1, 0 X2+Y2 1, X1=X2, Y1=Y2), and forming a layer 33 made of Alx3Gay3In1-x3-y3N (includes 0≤X3≤1, 0≤Y3≤1, 0≤X3+Y3≤1, X1 or X2=X3, Y1 or Y2=Y3) for the purpose at the temperature that the single crystal is grown thereon.



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CLAIMS

[Claim(s)]
[Claim 1] It is 3 group nitride semiconductor (AlxGaYIn1-X-YN;X=0, Y= 0, and X=Y=0 are included) on the substrate of the different-species matter. In the technique of making it growing up The buffer layer which formed Alx1GaY1In1-x1-Y1N (0 <=x1 <=1 and 0 <=Y 1<=1 and 0 <=x1+Y 1<=1) on the aforementioned substrate at the temperature a single crystal does not grow up to be, It is Alx2GaY2In1-x2-Y2N (0 <=x2 <=1 and 0 <=Y 2<=1, 0 <=x2+Y 2<=1, x1=x2, and Y1=Y2 are included) at the temperature a single crystal grows up to be. The three or more layers laminating of the formed single crystal layer is carried out by turns. Alx3GaY3In1-x3-Y3N (0 <=x3 <=1 and 0 <=Y 3<=1, 0 <=x3+Y 3<=1, X1, or X2= -- X3, Y1, or Y2=Y3 is included) made into the purpose at the temperature a single crystal grows up to be on it **** -- having formed the layer which changes The manufacture technique of 3 group nitride semiconductor by which it is characterized.
[Claim 2] It is the manufacture technique of 3 group nitride semiconductor according to claim 1 which the aforementioned buffer layer thickness is 100-1000**, and is characterized by the aforementioned single crystal layer thickness being 500-3000**.
[Claim 3] The growth temperature of the aforementioned buffer layer is the manufacture technique of 3 group nitride semiconductor according to claim 1 characterized by being 350-800 degrees C.
[Claim 4] the aforementioned buffer layer -- AlN it is -- the aforementioned single crystal layer -- GaN it is -- the manufacture technique of 3 group nitride semiconductor according to claim 1 characterized by things
[Claim 5] the aforementioned substrate -- sapphire or SiC it is -- the manufacture technique of 3 group nitride semiconductor according to claim 1 characterized by things
[Claim 6] 3 group nitride semiconductor formed on the substrate of the different-species matter (AlxGaYIn1-X-YN;X=0, Y= 0, and X=Y=0 are included) In the semiconductor device used as the element layer The buffer layer which consists of Alx1GaY1In1-x1-Y1N (0 <=x1 <=1 and 0 <=Y 1<=1 and 0 <=x1+Y 1<=1) formed at the temperature a single crystal does not grow up to be on the aforementioned substrate between the aforementioned substrate and the aforementioned element layer, Alx2GaY2In1-x2-Y2N (0 <=x2 <=1 and 0 <=Y 2<=1, 0 <=x2+Y 2<=1, x1=x2, and Y1=Y2 are included) formed at the temperature a single crystal grows up to be **** -- that the interlayer who did the three or more layers laminating of the single crystal layer which changes by turns intervenes The semiconductor device by which it is characterized.
[Claim 7] It is the semiconductor device according to claim 6 which the aforementioned buffer layer thickness is 100-1000**, and is characterized by the aforementioned single crystal layer thickness being 500-3000**.
[Claim 8] The growth temperature of the aforementioned buffer layer is a semiconductor device according to claim 6 characterized by being 350-800 degrees C.
[Claim 9] the aforementioned buffer layer -- AlN it is -- the aforementioned single crystal layer -- GaN it is -- semiconductor device according to claim 6 characterized by things
[Claim 10] the aforementioned substrate -- sapphire or SiC it is -- semiconductor device according to claim 6 characterized by things
[Claim 11] The aforementioned element layer is a semiconductor device according to claim 6 characterized by being a light-corpuscle child's basal layer.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] this invention relates to the light emitting device which used 3 group nitride semiconductor.
[0002]
[Description of the Prior Art] A buffer layer is conventionally formed on silicon on sapphire as a blue laser diode, and it is AlGaInN on the buffer layer. The thing of the structure in which the double heterojunction of the compound semiconductor of a system was formed is known. Since the compound semiconductor is a transited [directly] type, it attracts attention from that luminous efficiency is high, making into the luminescent color blue it is [blue] one in three primary colors of the light, etc.
[0003]
[Problem(s) to be Solved by the Invention] However, the laser diode of the conventional above-mentioned structure is AlGaInN on the substrate of the different-species matter, although the buffer layer is used. In order to grow up the compound semiconductor of a system, crystallinity is not yet good. That is, this lattice defect is perpendicularly penetrated from the substrate side to the luminous layer, and the lattice defect density in a luminous layer exists about two 109-1010/cm. That this lattice defect density is high reduces luminous efficiency, and it is shortening the life of operation. It is AlGaInN which this invention is accomplished [AlGaInN] in order to solve the above-mentioned technical probrem, and grows up the purpose on a different-species matter substrate. It is improving the crystallinity of the compound semiconductor of a system and improving the property of the semiconductor device using the compound semiconductor.
[0004]
[Means for Solving the Problem] this invention is 3 group nitride semiconductor (AlxGaYIn1-X-YN;X=0, Y= 0, and X=Y=0 are included) on the substrate of the different-species matter. In the technique of making it growing up The buffer layer which formed Alx1GaY1In1-x1-Y1N (0 <=x1 <=1 and 0 <=Y 1<=1 and 0 <=x1+Y 1<=1) on the substrate at the temperature a single crystal does not grow up to be, It is Alx2GaY2In1-x2-Y2N (0 <=x2 <=1 and 0 <=Y 2<=1, 0 <=x2+Y 2<=1, x1=x2, and Y1=Y2 are included) at the temperature a single crystal grows up to be. The three or more layers laminating of the formed single crystal layer is carried out by turns. Alx3GaY3In1-x3-Y3N (0 <=x3 <=1 and 0 <=Y 3<=1, 0 <=x3+Y 3<=1, X1 or x2=x3, Y1, or Y2=Y3 is included) made into the purpose at the temperature a single crystal grows up to be on it **** -- it is characterized by forming the layer which changes Moreover, the characteristic feature of other invention is the semiconductor device which made the layer of Alx3GaY3In1-x3-Y3N formed such the basal layer of an element layer.
[0005] By this configuration, the lattice defect lengthwise prolonged from a substrate side is intercepted on the way by the repeat of a buffer layer and a single crystal layer, and it does not result in the layer of the single crystal made into the purpose. Especially, the trusion from a substrate side is confined in 50 - 1000** of the single crystal of a buffer layer, and prevents being spread in the upper layer. Therefore, the lattice defect density in the semiconductor layer for forming an element becomes low, and the single crystal semiconductor which consists of good Alx3GaY3In1-x3-Y3N also on the substrate of the different-species matter is obtained. Moreover, when an element is formed, having used the semiconductor of the single crystal as the basal layer, the crystallinity of the layer which forms an element can become high and the property of an element can be raised. When a light emitting device is formed especially, luminous efficiency, an element life, and photogenesis brightness can be improved.
[0006] making a buffer layer thickness into 100-1000**, and making a single crystal layer thickness into 500-3000** like claims 2 and 7, -- moreover, it can prevent efficiently being extended in the semiconductor layer which a lattice defect makes the purpose from a substrate side like claims 3 and 8 by making growth temperature of a buffer layer into 350-800 degrees C Moreover, distortion becomes large and is not desirable if a single crystal layer thickness exceeds 3000**.
[0007] Let a buffer layer and a single crystal layer be the nitride semiconductors of 4 yuan of general formula AlxGaYIn1-X-YN, 3 yuan, and 2 yuan. Especially like a claim 4, it is GaN about AlN and a single crystal layer in a buffer layer. GaN made into the purpose by carrying out The lattice defect density of a layer can be reduced greatly. Moreover, in a substrate, they are sapphire or SiC. A grade can be used. In addition, the number of repeats of a buffer layer and a single crystal layer is arbitrary. Moreover, it is desirable to carry out a temperature up as it is after the last buffer layer stratification, and to grow up a single crystal layer also from the simplicity of a process also from the crystallinity of a single crystal.
[0008]
[Example] The layer which consists of Alx3GaY3In1-x3-Y3N made into the purpose as follows was formed on silicon on sapphire. Each class is an organometallic compound vapor growth (it is described as "MOVPE" below). It was formed of the vapor growth to depend. the used gas -- NH3 Carrier gas H2, or N2 and trimethylgallium (Ga3 (CH3)) (it is described as "TMG"

below) Trimethylaluminum (aluminum3 (CH3)) (it is described as "TMA" below) it is .

[0009] First, thickness 100-400 washed with organic washing and heat treatment It is MOVPE about the silicon on sapphire 1 of the single crystal of mum. The susceptor laid in the reaction chamber of equipment is equipped. Next, gas phase etching of the silicon on sapphire 1 was carried out at the temperature of 1100 degrees C, passing H2 to a reaction chamber by part for rate-of-flow 2 liter/by the ordinary pressure.

[0010] next, temperature it falls to 400 degrees C -- making -- H2 -- a part for 20 liter/, and NH3 A part for 10 liter/, and TMA it supplies by part for 1.8x10 -five mols/, and is shown in drawing 1 -- as -- the buffer layer 21 of AlN -- abbreviation It was formed in the thickness of 500**. next, the temperature of silicon on sapphire 1 -- 1150 degrees C -- holding -- H2 -- a part for 20 liter/, and NH3 A part for 10 liter/, and TMG a part for 1.7x10 -four mols/-- supplying -- thickness 0.3 [about] GaN of mum **** -- the single crystal layer 31 which changes was formed

[0011] next, the temperature of silicon on sapphire 1 is again fallen up to 400 degree C -- making -- the same conditions as formation of the buffer layer 21 -- AlN of the thickness of 500** **** -- the buffer layer 22 which changes was formed next, the temperature of silicon on sapphire 1 -- again -- 1150 degrees C -- raising -- the same conditions as formation of the single crystal layer 31 -- thickness 0.3 GaN of mum **** -- the single crystal layer 32 which changes was formed Furthermore, the temperature of silicon on sapphire 1 was again reduced up to 400 degree C, and the buffer layer 23 was similarly formed on the single crystal layer 32. and the temperature of silicon on sapphire 1 -- again -- 1150 degrees C -- raising -- the same conditions as formation of the single crystal layer 31 -- thickness 1.5 GaN of mum **** -- the single crystal layer 33 made into the purpose which changes was formed

[0012] It is KOH about this single crystal layer 33. It etched, and surface dislocation density was picturized under the electronic-scanning microscope by the etch-pit method, and it measured. the result -- 8x105 cm2 it was . the former -- like -- a silicon-on-sapphire 1 top -- AlN of one layer **** -- GaN which forms the buffer layer 22 which changes and is made into the purpose on it **** -- since the etch-pit densities at the time of forming the single crystal layer which changes were 4x107 / cm2, the etch-pit density fell to 1/50 by the manufacture technique of this example

[0013] The ground which can decrease an etch pit by making a buffer layer into multilayer structure is considered as follows. The configuration of a pit is a hexagonal method by observation by the electron microscope. AlN GaN formed on a buffer layer It is the island-like crystal of a hexagonal method the early stages of growth. Then, a buffer layer is GaN in a crystal growth. Although covered, it is thought that a lattice defect fraction is left behind and serves as the pit of a hexagonal method too. However, AlN A buffer layer and GaN At making a single crystal layer into multiplex period structure, it is AlN. A layer is GaN. It is thought that it interferes well with a layer and the lattice defect was closed.

[0014] At the above-mentioned example, it is AlN in a buffer layer. Although used, they are GaN of other 2 yuan systems, and InN. AlGaN of a 3 yuan system, InGaN, and AlGaInN of a 4 yuan system A grade can be used. In this case, a buffer layer is formed at the low temperature a single crystal does not grow up to be, and the thickness has desirable 100 - 1000**. Moreover, even if the matter of the single crystal layer formed on a buffer layer has a buffer layer, the matter, and the same composition ratio, as for the different-species matter, a composition ratio may differ also from the of-the-same-kind matter. this single crystal layer -- GaN others -- AlGaN of the 3 yuan system of an arbitrary composition ratio, InGaN, and AlGaInN of the 4 yuan system of an arbitrary composition ratio It can use. The growth temperature of this single crystal layer is the temperature a single crystal can grow up to be. Generally, the domain of thickness of 500 - 3000** is desirable. Moreover, the number of times of a repeat of a buffer layer and a single crystal layer is arbitrary.

[0015] Furthermore, 3 group nitride semiconductor Alx3GaY3In1-x3-Y3N [of 2 yuan, 3 yuan, and 4 yuan] (0 <=x3 <=1 and 0 <=Y 3<=1 and 0 <=x3+Y 3<=1) of a system can be used for the semiconductor layer of the target single crystal.

[0016] Next, the laser diode 10 was manufactured using this manufacture technique. In drawing 1 , the laser diode 10 has silicon on sapphire 1, and the interlayer 2 is formed on the silicon on sapphire 1. The interlayer 2 is the same as that of the structure shown in drawing 1 . namely, the interlayer 2 -- AlN of thickness 500 ** **** -- the buffer layer 21 and thickness 0.3 which change mum **** -- AlN of single crystal layer 31,500 ** which changes **** -- the buffer layer 22 and thickness 0.3 which change mum **** -- AlN of single crystal layer 32,500 ** which changes **** -- it consists of the multilayer structure of the buffer layer 23 which changes

[0017] On the interlayer 2, and in order The silicon dope GaN of 2x1018/cm3 of concentration of electrons since -- high carrier concentration n+ which changes A layer 3 and concentration of electrons AlGaN of the silicon dope of 2x1018/cm3 since -- InGaN of the clad layer 4 of n conduction type which changes, and about 0.05 micrometers of thicknesss **** -- AlGaN by which magnesium was doped by the barrier layer 5 which changes, 1x1018/cm3 of hole concentration, and 2x1020/cm3 of concentration **** -- the clad layer 61 of p conduction type which changes -- 1x1018/cm3 of hole concentration, and magnesium concentration GaN of the magnesium dope of 2x1020/cm3 **** -- the contact layer 62 which changes is formed and SiO two-layer 9 forms on the contact layer 62 -- having -- SiO two-layer -- the electrode 7 which consists of nickel joined to the contact layer 62 through the window part of 9 is formed Furthermore, high carrier concentration n+ The electrode 8 which consists of nickel joined to the layer 3 is formed on the layer 3.

[0018] Next, the manufacture technique of the laser diode 10 of this structure is explained. The above-mentioned laser diode 10 is MOVPE mentioned above. It was manufactured by the vapor growth to depend. The used gas is NH3. Carrier gas H2, or N2 and TMG TMA Trimethylindium (In3 (CH3)) (it is described as "TMI" below) They are a silane (SiH4) and magnesium cyclopentadienyl (Mg2 (C5H5)) (it is described as "CP2Mg" below).

[0019] First, thickness 100-400 washed with organic washing and heat treatment It is MOVPE about the silicon on sapphire 1 of the single crystal of mum. The susceptor laid in the reaction chamber of equipment is equipped. Next, gas phase etching of the

silicon on sapphire 1 was carried out at the temperature of 1100 degrees C, passing H2 to a reaction chamber by part for rate-of-flow 2 liter/by the ordinary pressure.

[0020] Next, temperature It is made to fall to 400 degrees C, and they are a part for 20 liter/, and NH3 about H2. A part for 10 liter/, and TMA It supplies by part for 1.8x10 -five mols/, and is AlN. It is abbreviation about the buffer layer 21. It formed in the thickness of 500**. next, the temperature of silicon on sapphire 1 -- 1150 degrees C -- holding -- H2 -- a part for 20 liter/, and NH3 A part for 10 liter/, and TMG a part for 1.7x10-4 **/-- for 4 minutes -- supplying -- thickness 0.3 [about] GaN of mum **** -- the single crystal layer 31 which changes was formed

[0021] next, the temperature of silicon on sapphire 1 is again fallen up to 400 degree C -- making -- the same conditions as formation of the buffer layer 21 -- AlN of the thickness of 500** **** -- the buffer layer 22 which changes was formed next, the temperature of silicon on sapphire 1 -- again -- 1150 degrees C -- raising -- the same conditions as formation of the single crystal layer 31 -- thickness 0.3 GaN of mum **** -- the single crystal layer 32 which changes was formed Furthermore, the temperature of silicon on sapphire 1 was again reduced up to 400 degree C, and the buffer layer 23 was similarly formed on the single crystal layer 32.

[0022] The temperature of silicon on sapphire 1 is held at 1150 degrees C. H2 A part for next, 20 liter/, NH3 A part for 10 liter/, and TMG It is 0.86 ppm by part for 1.7x10-4 **/, and H2 gas. The diluted silane is supplied by part for 200ml/. thickness 2.2 about] mum and concentration of electrons GaN of the silicon dope of 2x1018/cm3 **** -- high carrier concentration n+ which changes The layer 3 was formed.

[0023] The temperature of silicon on sapphire 1 is held at 1100 degrees C. N2 or H2 A part for next, 10 liter/, NH3 A part for 10 liter/, and TMG 1.12x10 -four mol a part for /and TMA It is 0.86 ppm by 0.47x10 -four mol part [for /], and H2 gas. The diluted silane is supplied by part for 10x10-9mol/. AlGaN of the silicon dope of 2x1018/cm3 of concentration **** -- the clad layer 4 of n conduction type which changes was formed

[0024] then, temperature -- 850 ** -- holding -- N2 or H2 -- a part for 20 liter/, and NH3 A part for 10 liter/, and TMG 1.53x10 -four mol a part for /and TMI a part for 0.02x10 -four mols/-- supplying -- 0.05-micrometer InGaN **** -- the barrier layer 5 which changes was formed

[0025] then, temperature -- 1100 degrees C -- holding -- N2 or H2 -- a part for 20 liter/, and NH3 A part for 10 liter/, and TMG 1.12x10 -four mol a part for /and TMA 0.47x10 -four mol a part for /and CP2Mg a part for 2x10 -four mols/-- supplying -- AlGaN of a magnesium (Mg) dope **** -- the clad layer 61 of p conduction type which changes was formed The concentration of the magnesium of the clad layer 61 is 2x1020/cm3. In this status, the clad layer 61 is still resistivity 108. It is an insulator more than omegacm.

[0026] then, temperature -- 1100 degrees C -- holding -- N2 or H2 -- a part for 20 liter/, and NH3 A part for 10 liter/, and TMG 1.12x10 -four mol a part for /and CP2Mg a part for 4x10 -four mols/-- supplying -- thickness 0.2 [about] GaN of the magnesium (Mg) dope of mum **** -- the contact layer 62 which changes was formed Concentration of the magnesium of the contact layer 62 It is 2x1020/cm3. In this status, the contact layer 62 is still resistivity 108. It is an insulator more than omegacm.

[0027] Next, the contact layer 62 and the clad layer 61 are 1x1018/cm3 of hole concentration, and resistivity by the electron beam irradiation. It became p conduction-type semiconductor of 2ohmcm. Thus, the wafer of multilayer structure was obtained.

[0028] next, the contact layer 62 top -- sputtering -- SiO two-layer -- 9 was formed in the thickness of 2000** and the photoresist was applied on the SiO two-layer 9 And it sets on the contact layer 62 with a ********** graph, and is high carrier concentration n+. The photoresist of the electrode formation site to a layer 3 was removed. next, the SiO two-layer which is not covered by the photoresist -- 9 was removed by the hydrofluoric-acid system etching reagent

[0029] Next, after supplying and carrying out dry etching of 2 and the BCl3 gas at a rate for 10 ml/degree of vacuum 0.04Torr and 0.44W [/cm] RF power, dry etching of the contact layer 62 of the site which is not covered by a photoresist and SiO two-layer 9, the clad layer 61, the barrier layer 5, and the clad layer 4 was carried out by Ar. this process -- high carrier concentration n+ the hole for electrode extraction to a layer 3 -- A was formed

[0030] next, SiO two-layer -- 9 -- receiving -- an application of a photoresist, a photolithography process, and wet etching -- carrying out -- SiO two-layer -- the aperture was formed in the electrode formation site of the contact layer 62 of 9

[0031] Next, all over the upper [of a sample], the vacuum evaporationo of the nickel is carried out uniformly, and it passes through an application of a photoresist, a photolithography process, and an etching process, and is high carrier concentration n+. The electrodes 8 and 7 to the layer 3 and the contact layer 62 were formed. Then, like the above, the processed wafer was cut in the shape of a strip of paper in the length orientation of the mold cavity of laser, the cleavage was carried out in the orientation right-angled, and the laser diode chip was formed in it.

[0032] thus, AlN of the low-temperature growth by the interlayer 2 **** -- considering as the multiplex layer of the buffer layer which changes -- high carrier concentration n+ The crystallinity of a layer 3, the clad layer 4, the barrier layer 5, the clad layer 61, and the contact layer 62 was able to be raised.

[0033] In addition, an interlayer 2 can consider various deformation, as the example of the manufacture technique showed. Moreover, at the above-mentioned example, it is InGaN about the structure of a barrier layer 5. Although considered as the monolayer, thickness is InGaN of 100 **, respectively. GaN The constituted multiplex quantum well structure is sufficient. The thickness of a barrier layer 5 is 100 - 1000**. Various kinds of GaNs which contain light-corpuscle children, such as light emitting diode and a photo detector, although this example explained the laser diode It cannot be overemphasized that it is applicable to a system electron device.

[0034] Moreover, generally AlxGayIn1-x-yN is sufficient as the clad layers 4 and 61 and the barrier layer 5. Composition Ratio

x: y:1-x-y is determined according to the oscillation wavelength of laser.
[0035] Heat treatment besides an electron beam irradiation, heat treatment in N2 plasma gas, and laser radiation can perform p mold-ization.

[Translation done.]

Field

[Field of the Invention] this invention relates to the light emitting device which used 3 group nitride semiconductor.

[Translation done.]

Technique

[Description of the Prior Art] A buffer layer is conventionally formed on silicon on sapphire as a blue laser diode, and it is AlGaInN on the buffer layer. The thing of the structure in which the double heterojunction of the compound semiconductor of a system was formed is known. Since the compound semiconductor is a transited [directly] type, it attracts attention from that luminous efficiency is high, making into the luminescent color blue it is [blue] one in three primary colors of the light, etc.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] However, the laser diode of the conventional above-mentioned structure is AlGaInN on the substrate of the different-species matter, although the buffer layer is used. In order to grow up the compound semiconductor of a system, crystallinity is not yet good. That is, this lattice defect is perpendicularly penetrated from the substrate side to the luminous layer, and the lattice defect density in a luminous layer exists about two 109-1010/cm. That this lattice defect density is high reduces luminous efficiency, and it is shortening the life of operation. It is AlGaInN which this invention is accomplished [AlGaInN] in order to solve the above-mentioned technical probrem, and grows up the purpose on a different-species matter substrate. It is improving the crystallinity of the compound semiconductor of a system and improving the property of the semiconductor device using the compound semiconductor.

[Translation done.]

MEANS

[Means for Solving the Problem] this invention is 3 group nitride semiconductor (AlxGaYIn1-X-YN;X=0, Y= 0, and X=Y=0 are included) on the substrate of the different-species matter. In the technique of making it growing up The buffer layer which formed Alx1GaY1In1-x1-Y1N (0 <=x1 <=1 and 0 <=Y 1<=1 and 0 <=x1+Y 1<=1) on the substrate at the temperature a single crystal does not grow up to be, It is Alx2GaY2In1-x2-Y2N (0 <=x2 <=1 and 0 <=Y 2<=1, 0 <=x2+Y 2<=1, x1=x2, and Y1=Y2 are included) at the temperature a single crystal grows up to be. The three or more layers laminating of the formed single crystal layer is carried out by turns. Alx3GaY3In1-x3-Y3N (0 <=x3 <=1 and 0 <=Y 3<=1, 0 <=x3+Y 3<=1, X1 or x2=x3, Y1, or Y2=Y3 is included) made into the purpose at the temperature a single crystal grows up to be on it **** -- it is characterized by forming the layer which changes Moreover, the characteristic feature of other invention is the semiconductor device which made the layer of Alx3GaY3In1-x3-Y3N formed such the basal layer of an element layer.
[0005] By this configuration, the lattice defect lengthwise prolonged from a substrate side is intercepted on the way by the repeat of a buffer layer and a single crystal layer, and it does not result in the layer of the single crystal made into the purpose. Especially, the trusion from a substrate side is confined in 50 - 1000** of the single crystal of a buffer layer, and prevents being spread in the upper layer. Therefore, the lattice defect density in the semiconductor layer for forming an element becomes low, and the single crystal semiconductor which consists of good Alx3GaY3In1-x3-Y3N also on the substrate of the different-species matter is obtained. Moreover, when an element is formed, having used the semiconductor of the single crystal as the basal layer, the crystallinity of the layer which forms an element can become high and the property of an element can be raised. When a light emitting device is formed especially, luminous efficiency, an element life, and photogenesis brightness can be improved.
[0006] making a buffer layer thickness into 100-1000**, and making a single crystal layer thickness into 500-3000** like claims 2 and 7, -- moreover, it can prevent efficiently being extended in the semiconductor layer which a lattice defect makes the purpose from a substrate side like claims 3 and 8 by making growth temperature of a buffer layer into 350-800 degrees C Moreover, distortion becomes large and is not desirable if a single crystal layer thickness exceeds 3000**.
[0007] Let a buffer layer and a single crystal layer be the nitride semiconductors of 4 yuan of general formula AlxGaYIn1-X-YN, 3 yuan, and 2 yuan. Especially like a claim 4, it is GaN about AlN and a single crystal layer in a buffer layer. GaN made into the purpose by carrying out The lattice defect density of a layer can be reduced greatly. Moreover, in a substrate, they are sapphire or SiC. A grade can be used. In addition, the number of repeats of a buffer layer and a single crystal layer is arbitrary. Moreover, it is desirable to carry out a temperature up as it is after the last buffer layer stratification, and to grow up a single crystal layer also from the simplicity of a process also from the crystallinity of a single crystal.

[Translation done.]

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EXAMPLE

[Example] The layer which consists of Alx3GaY3In1-x3-Y3N made into the purpose as follows was formed on silicon on sapphire. Each class is an organometallic compound vapor growth (it is described as "M0VPE" below). It was formed of the vapor growth to depend. the used gas -- NH3 Carrier gas H2, or N2 and trimethylgallium (Ga3 (CH3)) (it is described as "TMG" below) Trimethylaluminum (aluminum3 (CH3)) (it is described as "TMA" below) it is .
[0009] First, thickness 100-400 washed with organic washing and heat treatment It is M0VPE about the silicon on sapphire 1 of the single crystal of mum. The susceptor laid in the reaction chamber of equipment is equipped. Next, gas phase etching of the silicon on sapphire 1 was carried out at the temperature of 1100 degrees C, passing H2 to a reaction chamber by part for rate-of-flow 2 liter/by the ordinary pressure.
[0010] next, temperature it falls to 400 degrees C -- making -- H2 -- a part for 20 liter/, and NH3 A part for 10 liter/, and TMA it supplies by part for 1.8x10 -five mols/, and is shown in drawing 1 -- as -- the buffer layer 21 of AlN -- abbreviation It was formed in the thickness of 500**. next, the temperature of silicon on sapphire 1 -- 1150 degrees C -- holding -- H2 -- a part for 20 liter/, and NH3 A part for 10 liter/, and TMG a part for 1.7x10 -four mols/-- supplying -- thickness 0.3 [about] GaN of mum **** -- the single crystal layer 31 which changes was formed
[0011] next, the temperature of silicon on sapphire 1 is again fallen up to 400 degree C -- making -- the same conditions as formation of the buffer layer 21 -- AlN of the thickness of 500** **** -- the buffer layer 22 which changes was formed next, the temperature of silicon on sapphire 1 -- again -- 1150 degrees C -- raising -- the same conditions as formation of the single crystal layer 31 -- thickness 0.3 GaN of mum **** -- the single crystal layer 32 which changes was formed Furthermore, the temperature of silicon on sapphire 1 was again reduced up to 400 degree C, and the buffer layer 23 was similarly formed on the single crystal layer 32. and the temperature of silicon on sapphire 1 -- again -- 1150 degrees C -- raising -- the same conditions as formation of the single crystal layer 31 -- thickness 1.5 GaN of mum **** -- the single crystal layer 33 made into the purpose which changes was formed
[0012] It is KOH about this single crystal layer 33. It etched, and surface dislocation density was picturized under the electronic-scanning microscope by the etch-pit method, and it measured. the result -- 8x105 cm2 it was . the former -- like -- a silicon-on-sapphire 1 top -- AlN of one layer **** -- GaN which forms the buffer layer 22 which changes and is made into the purpose on it **** -- since the etch-pit densities at the time of forming the single crystal layer which changes were 4x107 / cm2, the etch-pit density fell to 1/50 by the manufacture technique of this example
[0013] The ground which can decrease an etch pit by making a buffer layer into multilayer structure is considered as follows. The configuration of a pit is a hexagonal method by observation by the electron microscope. AlN GaN formed on a buffer layer It is the island-like crystal of a hexagonal method the early stages of growth. Then, a buffer layer is GaN in a crystal growth. Although covered, it is thought that a lattice defect fraction is left behind and serves as the pit of a hexagonal method too. However, AlN A buffer layer and GaN At making a single crystal layer into multiplex period structure, it is AlN. A layer is GaN. It is thought that it interferes well with a layer and the lattice defect was closed.
[0014] At the above-mentioned example, it is AlN in a buffer layer. Although used, they are GaN of other 2 yuan systems, and InN. AlGaN of a 3 yuan system, InGaN, and AlGaInN of a 4 yuan system A grade can be used. In this case, a buffer layer is formed at the low temperature a single crystal does not grow up to be, and the thickness has desirable 100 - 1000**. Moreover, even if the matter of the single crystal layer formed on a buffer layer has a buffer layer, the matter, and the same composition ratio, as for the different-species matter, a composition ratio may differ also from the of-the-same-kind matter. this single crystal layer -- GaN others -- AlGaN of the 3 yuan system of an arbitrary composition ratio, InGaN, and AlGaInN of the 4 yuan system of an arbitrary composition ratio It can use. The growth temperature of this single crystal layer is the temperature a single crystal can grow up to be. Generally, the domain of thickness of 500 - 3000** is desirable. Moreover, the number of times of a repeat of a buffer layer and a single crystal layer is arbitrary.
[0015] Furthermore, 3 group nitride semiconductor Alx3GaY3In1-x3-Y3N [of 2 yuan, 3 yuan, and 4 yuan] (0 <=x3 <=1 and 0 <=Y 3<=1 and 0 <=x3+Y 3<=1) of a system can be used for the semiconductor layer of the target single crystal.
[0016] Next, the laser diode 10 was manufactured using this manufacture technique. In drawing 1 , the laser diode 10 has silicon on sapphire 1, and the interlayer 2 is formed on the silicon on sapphire 1. The interlayer 2 is the same as that of the structure shown in drawing 1 . namely, the interlayer 2 -- AlN of thickness 500 ** **** -- the buffer layer 21 and thickness 0.3 which change mum **** -- AlN of single crystal layer 31,500 ** which changes **** -- the buffer layer 22 and thickness 0.3 which change mum **** -- AlN of single crystal layer 32,500 ** which changes **** -- it consists of the multilayer structure of the buffer layer 23 which changes

[0017] On the interlayer 2, and in order The silicon dope GaN of 2x1018/cm3 of concentration of electrons since -- high carrier concentration n+ which changes A layer 3 and concentration of electrons AlGaN of the silicon dope of 2x1018/cm3 since -- InGaN of the clad layer 4 of n conduction type which changes, and about 0.05 micrometers of thicknesss **** -- AlGaN by which magnesium was doped by the barrier layer 5 which changes, 1x1018/cm3 of hole concentration, and 2x1020/cm3 of concentration **** -- the clad layer 61 of p conduction type which changes -- 1x1018/cm3 of hole concentration, and magnesium concentration GaN of the magnesium dope of 2x1020/cm3 **** -- the contact layer 62 which changes is formed and SiO two-layer 9 forms on the contact layer 62 -- having -- SiO two-layer -- the electrode 7 which consists of nickel joined to the contact layer 62 through the window part of 9 is formed Furthermore, high carrier concentration n+ The electrode 8 which consists of nickel joined to the layer 3 is formed on the layer 3.

[0018] Next, the manufacture technique of the laser diode 10 of this structure is explained. The above-mentioned laser diode 10 is MOVPE mentioned above. It was manufactured by the vapor growth to depend. The used gas is NH3. Carrier gas H2, or N2 and TMG TMA Trimethylindium (In3 (CH3)) (it is described as "TMI" below) They are a silane (SiH4) and magnesium cyclopentadienyl (Mg2 (C5H5)) (it is described as "CP2Mg" below).

[0019] First, thickness 100-400 washed with organic washing and heat treatment It is MOVPE about the silicon on sapphire 1 of the single crystal of mum. The susceptor laid in the reaction chamber of equipment is equipped. Next, gas phase etching of the silicon on sapphire 1 was carried out at the temperature of 1100 degrees C, passing H2 to a reaction chamber by part for rate-of-flow 2 liter/by the ordinary pressure.

[0020] Next, temperature It is made to fall to 400 degrees C, and they are a part for 20 liter/, and NH3 about H2. A part for 10 liter/, and TMA It supplies by part for 1.8x10 -five mols/, and is AlN. It is abbreviation about the buffer layer 21. It formed in the thickness of 500**. next, the temperature of silicon on sapphire 1 -- 1150 degrees C -- holding -- H2 -- a part for 20 liter/, and NH3 A part for 10 liter/, and TMG a part for 1.7x10-4 **/-- for 4 minutes -- supplying -- thickness 0.3 [about] GaN of mum **** -- the single crystal layer 31 which changes was formed

[0021] next, the temperature of silicon on sapphire 1 is again fallen up to 400 degree C -- making -- the same conditions as formation of the buffer layer 21 -- AlN of the thickness of 500** **** -- the buffer layer 22 which changes was formed next, the temperature of silicon on sapphire 1 -- again -- 1150 degrees C -- raising -- the same conditions as formation of the single crystal layer 31 -- thickness 0.3 GaN of mum **** -- the single crystal layer 32 which changes was formed Furthermore, the temperature of silicon on sapphire 1 was again reduced up to 400 degree C, and the buffer layer 23 was similarly formed on the single crystal layer 32.

[0022] The temperature of silicon on sapphire 1 is held at 1150 degrees C. H2 A part for next, 20 liter/, NH3 A part for 10 liter/, and TMG It is 0.86 ppm by part for 1.7x10-4 **/, and H2 gas. The diluted silane is supplied by part for 200ml/. thickness 2.2 about] mum and concentration of electrons GaN of the silicon dope of 2x1018/cm3 **** -- high carrier concentration n+ which changes The layer 3 was formed.

[0023] The temperature of silicon on sapphire 1 is held at 1100 degrees C. N2 or H2 A part for next, 10 liter/, NH3 A part for 10 liter/, and TMG 1.12x10 -four mol a part for /and TMA It is 0.86 ppm by 0.47x10 -four mol part [for /], and H2 gas. The diluted silane is supplied by part for 10x10-9mol/. AlGaN of the silicon dope of 2x1018/cm3 of concentration **** -- the clad layer 4 of n conduction type which changes was formed

[0024] then, temperature -- 850 ** -- holding -- N2 or H2 -- a part for 20 liter/, and NH3 A part for 10 liter/, and TMG 1.53x10 -four mol a part for /and TMI a part for 0.02x10 -four mols/-- supplying -- 0.05-micrometer InGaN **** -- the barrier layer 5 which changes was formed

[0025] then, temperature -- 1100 degrees C -- holding -- N2 or H2 -- a part for 20 liter/, and NH3 A part for 10 liter/, and TMG 1.12x10 -four mol a part for /and TMA 0.47x10 -four mol a part for /and CP2Mg a part for 2x10 -four mols/-- supplying -- AlGaN of a magnesium (Mg) dope **** -- the clad layer 61 of p conduction type which changes was formed The concentration of the magnesium of the clad layer 61 is 2x1020/cm3. In this status, the clad layer 61 is still resistivity 108. It is an insulator more than omegacm.

[0026] then, temperature -- 1100 degrees C -- holding -- N2 or H2 -- a part for 20 liter/, and NH3 A part for 10 liter/, and TMG 1.12x10 -four mol a part for /and CP2Mg a part for 4x10 -four mols/-- supplying -- thickness 0.2 [about] GaN of the magnesium (Mg) dope of mum **** -- the contact layer 62 which changes was formed Concentration of the magnesium of the contact layer 62 It is 2x1020/cm3. In this status, the contact layer 62 is still resistivity 108. It is an insulator more than omegacm.

[0027] Next, the contact layer 62 and the clad layer 61 are 1x1018/cm3 of hole concentration, and resistivity by the electron beam irradiation. It became p conduction-type semiconductor of 2ohmcm. Thus, the wafer of multilayer structure was obtained.

[0028] next, the contact layer 62 top -- sputtering -- SiO two-layer -- 9 was formed in the thickness of 2000** and the photoresist was applied on the SiO two-layer 9 And it sets on the contact layer 62 with a ********** graph, and is high carrier concentration n+. The photoresist of the electrode formation site to a layer 3 was removed. next, the SiO two-layer which is not covered by the photoresist -- 9 was removed by the hydrofluoric-acid system etching reagent

[0029] Next, after supplying and carrying out dry etching of 2 and the BCl3 gas at a rate for 10 ml/degree of vacuum 0.04Torr and 0.44W [/cm] RF power, dry etching of the contact layer 62 of the site which is not covered by a photoresist and SiO two-layer 9, the clad layer 61, the barrier layer 5, and the clad layer 4 was carried out by Ar. this process -- high carrier concentration n+ the hole for electrode extraction to a layer 3 -- A was formed

[0030] next, SiO two-layer -- 9 -- receiving -- an application of a photoresist, a photolithography process, and wet etching -- carrying out -- SiO two-layer -- the aperture was formed in the electrode formation site of the contact layer 62 of 9

[0031] Next, all over the upper [of a sample], the vacuum evaporationo of the nickel is carried out uniformly, and it passes through an application of a photoresist, a photolithography process, and an etching process, and is high carrier concentration n+. The electrodes 8 and 7 to the layer 3 and the contact layer 62 were formed. Then, like the above, the processed wafer was cut in the shape of a strip of paper in the length orientation of the mold cavity of laser, the cleavage was carried out in the orientation right-angled, and the laser diode chip was formed in it.

[0032] thus, AlN of the low-temperature growth by the interlayer 2 **** -- considering as the multiplex layer of the buffer layer which changes -- high carrier concentration n+ The crystallinity of a layer 3, the clad layer 4, the barrier layer 5, the clad layer 61, and the contact layer 62 was able to be raised.

[0033] In addition, an interlayer 2 can consider various deformation, as the example of the manufacture technique showed. Moreover, at the above-mentioned example, it is InGaN about the structure of a barrier layer 5. Although considered as the monolayer, thickness is InGaN of 100 **, respectively. GaN The constituted multiplex quantum well structure is sufficient. The thickness of a barrier layer 5 is 100 - 1000**. Various kinds of GaNs which contain light-corpuscle children, such as light emitting diode and a photo detector, although this example explained the laser diode It cannot be overemphasized that it is applicable to a system electron device.

[0034] Moreover, generally AlxGayIn1-x-yN is sufficient as the clad layers 4 and 61 and the barrier layer 5. Composition Ratio x: y:1-x-y is determined according to the oscillation wavelength of laser.

[0035] Heat treatment besides an electron beam irradiation, heat treatment in N2 plasma gas, and laser radiation can perform p mold-ization.

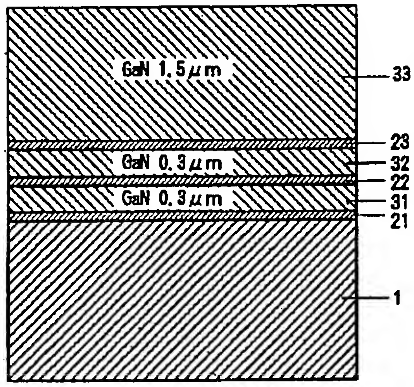
[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] The cross section of a semiconductor layer having shown the manufacture technique concerning the concrete example of this invention.
[Drawing 2] The block diagram having shown the configuration of the laser diode concerning the concrete example of this invention.
[Description of Notations]
10 -- Laser diode
1 -- Silicon on sapphire
2 -- Interlayer
21, 22, 23 -- Buffer layer
31, 32 -- Single crystal layer
3 -- Quantity carrier concentration n+ Layer
4 -- Clad layer
5 -- Barrier layer
61 -- Clad layer
62 -- Contact layer
7, 8 -- Electrode
9 -- SiO two-layer

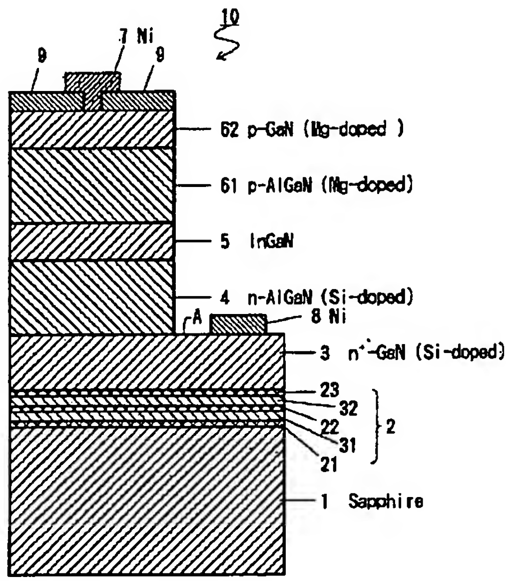
[Translation done.]

Drawing selection Drawing 1



[Translation done.]

Drawing selection Drawing 2



[Translation done.]